Toward the Seasonal Prediction of Atmospheric Rivers over the northeast Pacific Ocean and western North America

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MAPP Modeling, Analysis, Predictions, and Projections

Stony Brook University

* Kim and Zhou (*submitted*)

Atmospheric River (AR)

- Filamentary features (400-600 km wide, >2000 km long)
- Transports ~90 % of the water vapor from the tropics into the extra-tropics.
- Induce heavy wintertime precipitation along the west coast states.
- Provide up to 50 % of California's water supply.

Total precipitable water: Jan-27 to 29, 2016 (hourly)

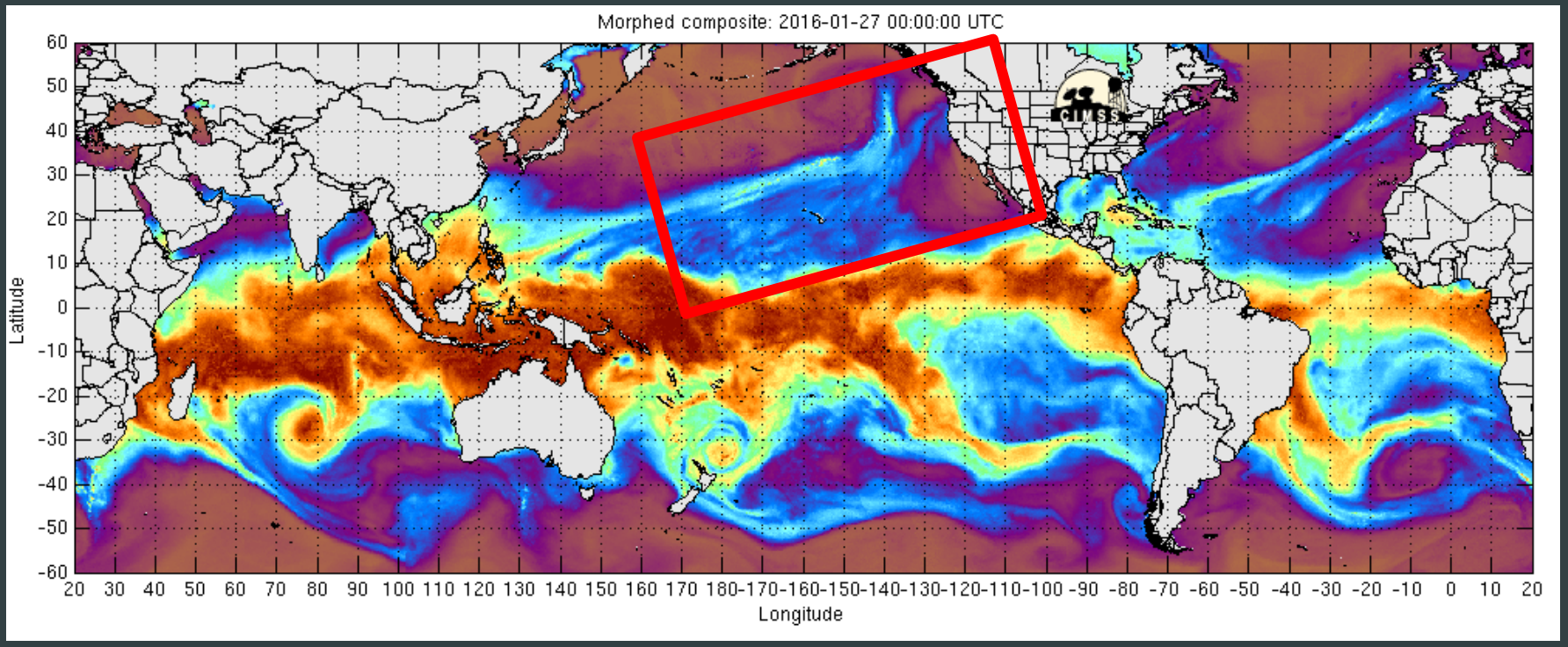


Image credit: CIMSS/University of Wisconsin, Madison

ENSO induced circulation change

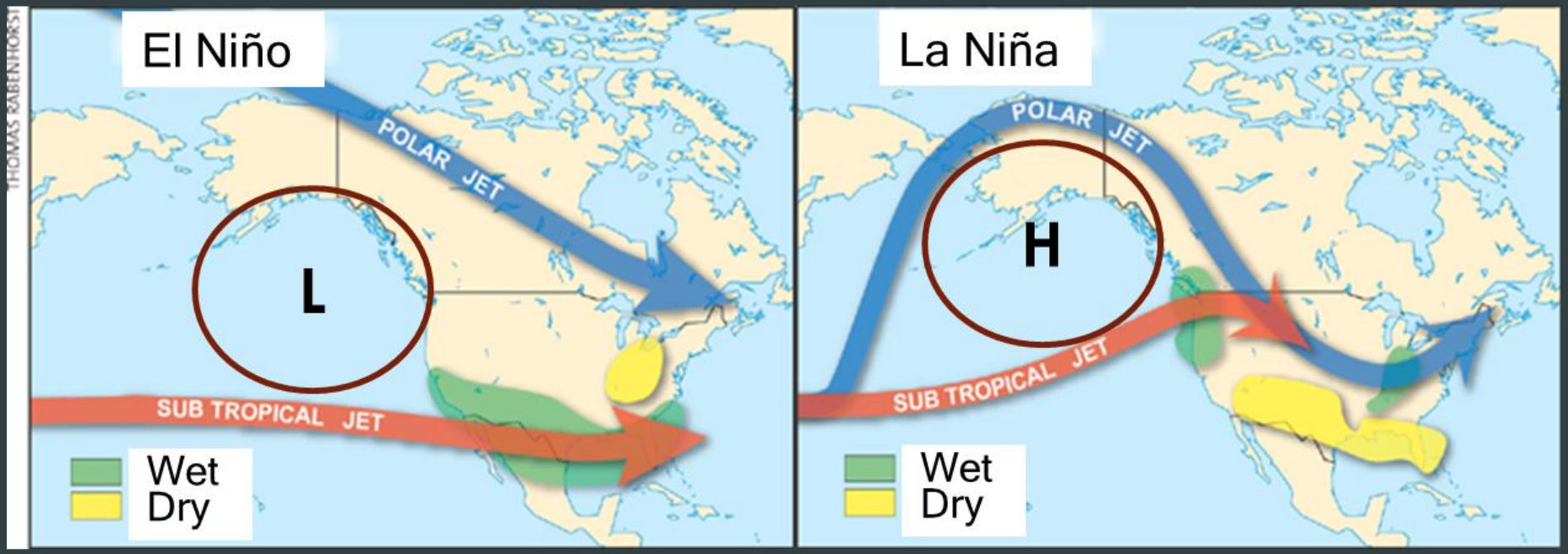


Figure: http://www.weatherwise.org/

Contents

Research questions

- How does ENSO (EP vs. CP) impact on ARs and moisture transport?
- How well do the current models (NMME) predict the AR activity?

Approach

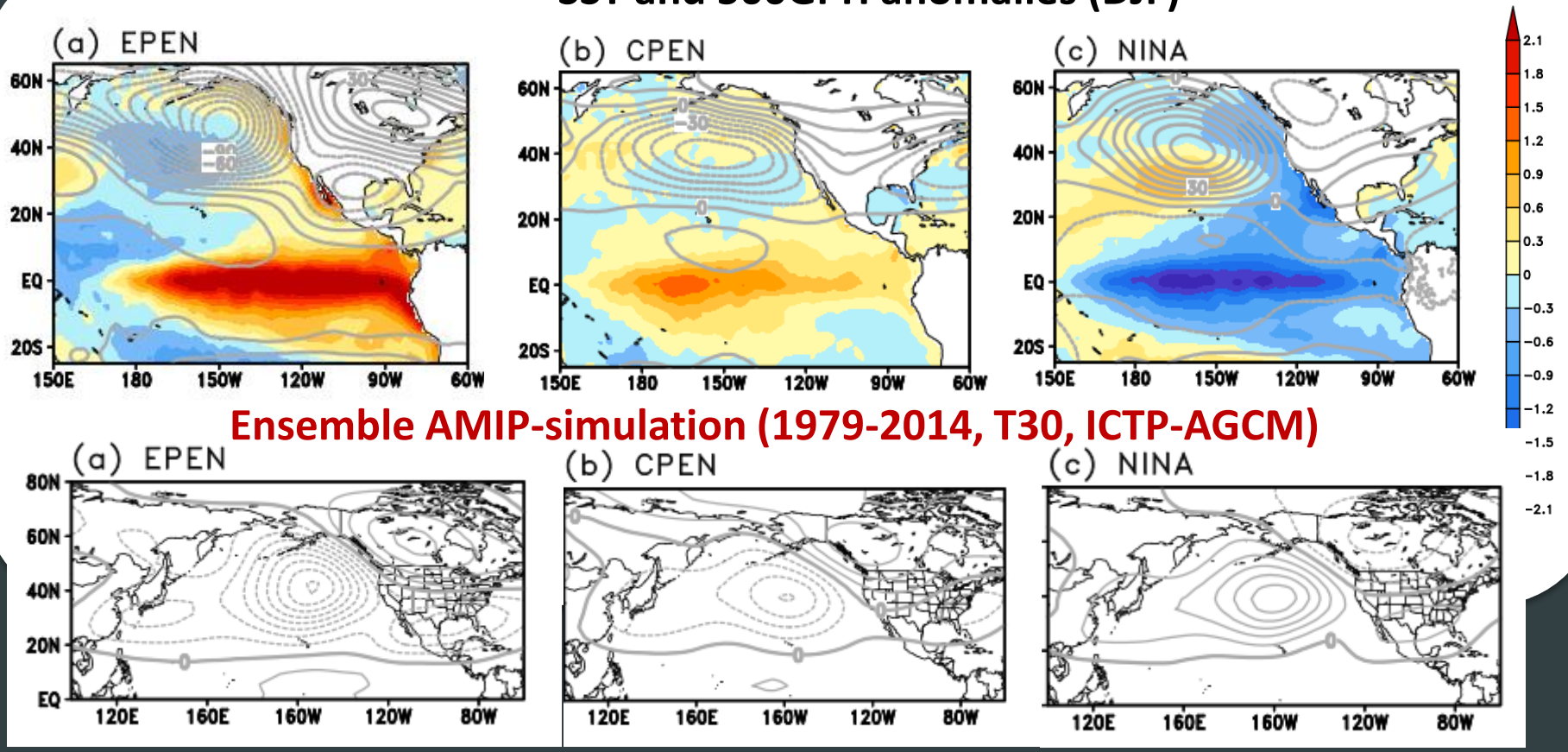
- AR activity (frequency, intensity, landfall location)
  in the three ENSO phases: EP, CP El Nino, and La Nina

- Causes of change in seasonal moisture transport related to ENSO
  - Low-frequency vs. synoptic variability
  - Dynamic vs. thermodynamic factors
  - Divergence vs. advection term (moisture budget)

- AR-ENSO prediction in NMME reforecasts

Three ENSO phases

SST and 500GPH anomalies (DJF)



Ensemble AMIP-simulation (1979-2014, T30, ICTP-AGCM)

- Boreal Winter (DJF), HadISST
- EP El Niño (4 years): 82/83, 91/92, 97/98, **2015/16**
  CP El Niño (4 years): 94/95, 2002/03, 04/05, 09/10
  La Niña (6 years): 84/85, 88/89, 98/99, 99/00, 07/08, 10/11

(Selection is based on Nino indices, Kim et al. 2009, 2012)

AR definition

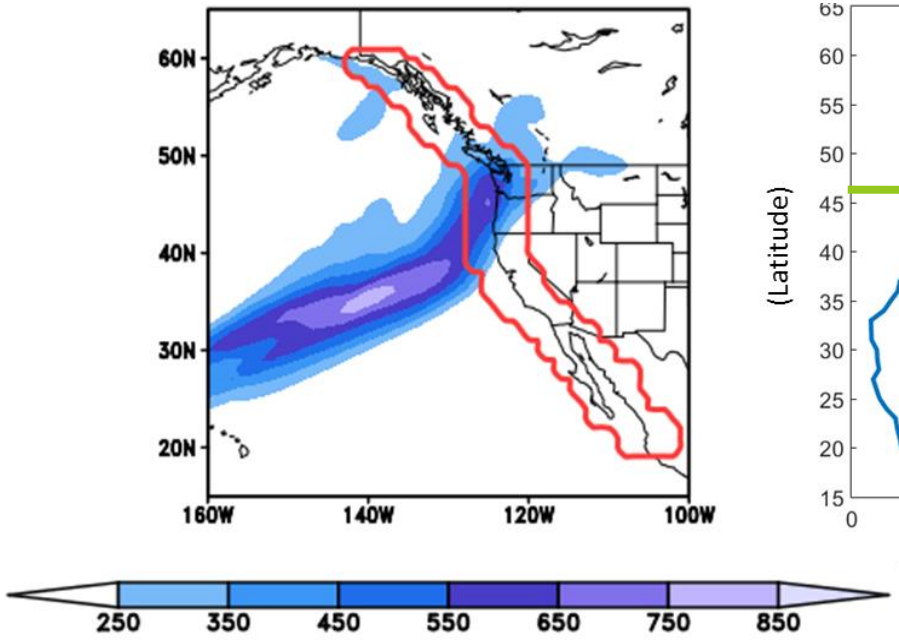
AR detection

- ERA-Interim: 6hr data from 1979/80-2015/16, DJF
- Vertically-integrated moisture flux ≥ 250 kg/m/s (Rutz et al. 2014)

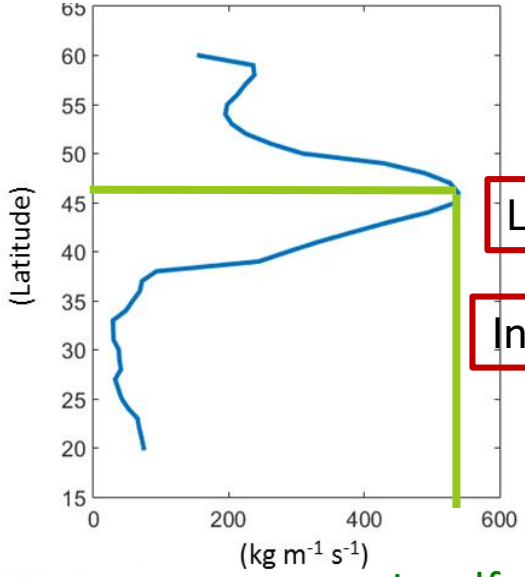
$$Q = \frac{1}{g}\int_{Ps}^{300} \vec{V} \cdot q \, dP$$

Landfalling AR

(a) Q, Jan 28, 2016



(b) Averaged Q along the coastal area



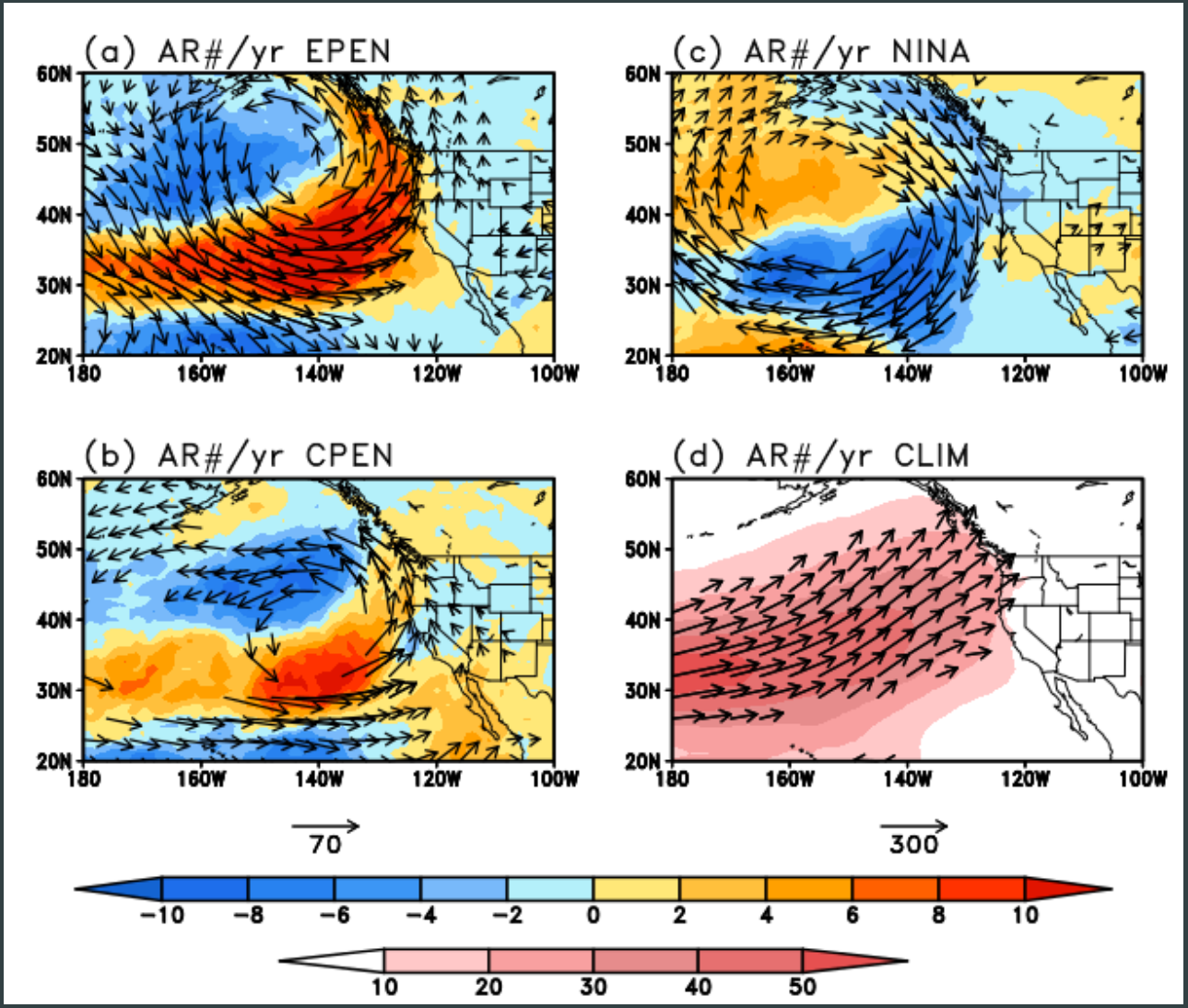
Latitude: 46°N

Intensity: 538.8kg m^{-1} s^{-1}

Landfalling AR > 250

Extreme landfalling AR > 450

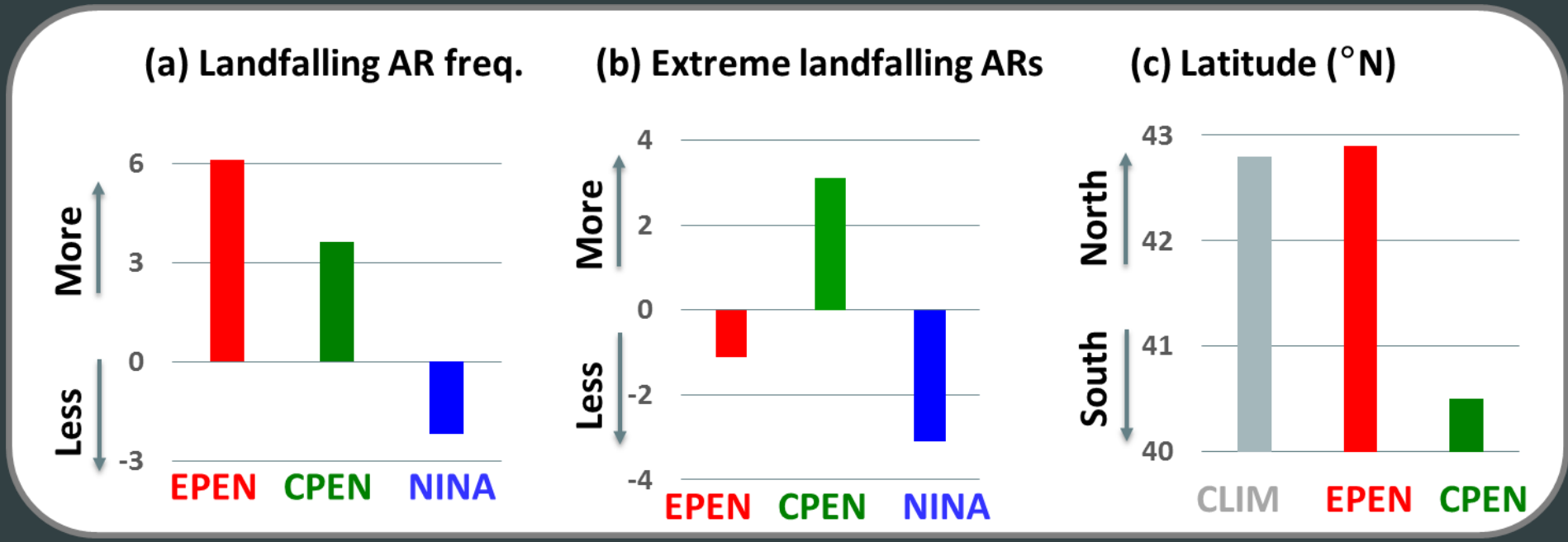
AR Frequency



Shading: Frequency (#/year)
Vector: Moisture flux

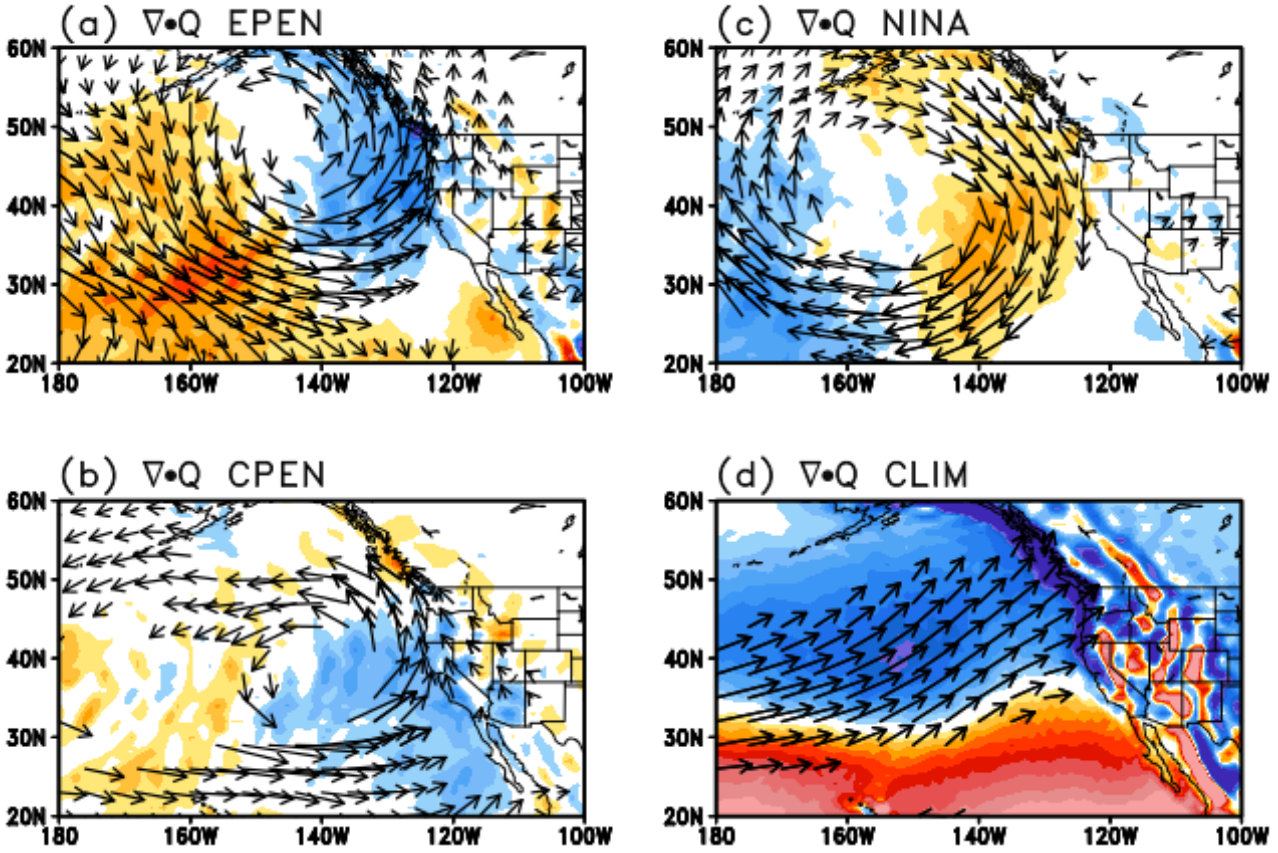
* The vectors shown exceed the 90 % significant level.

Landfalling AR



- EPEN → More landfalling ARs in the northwest
- CPEN → More extreme ARs in the southwest due to the southward shift of the Low.

Moisture flux divergence



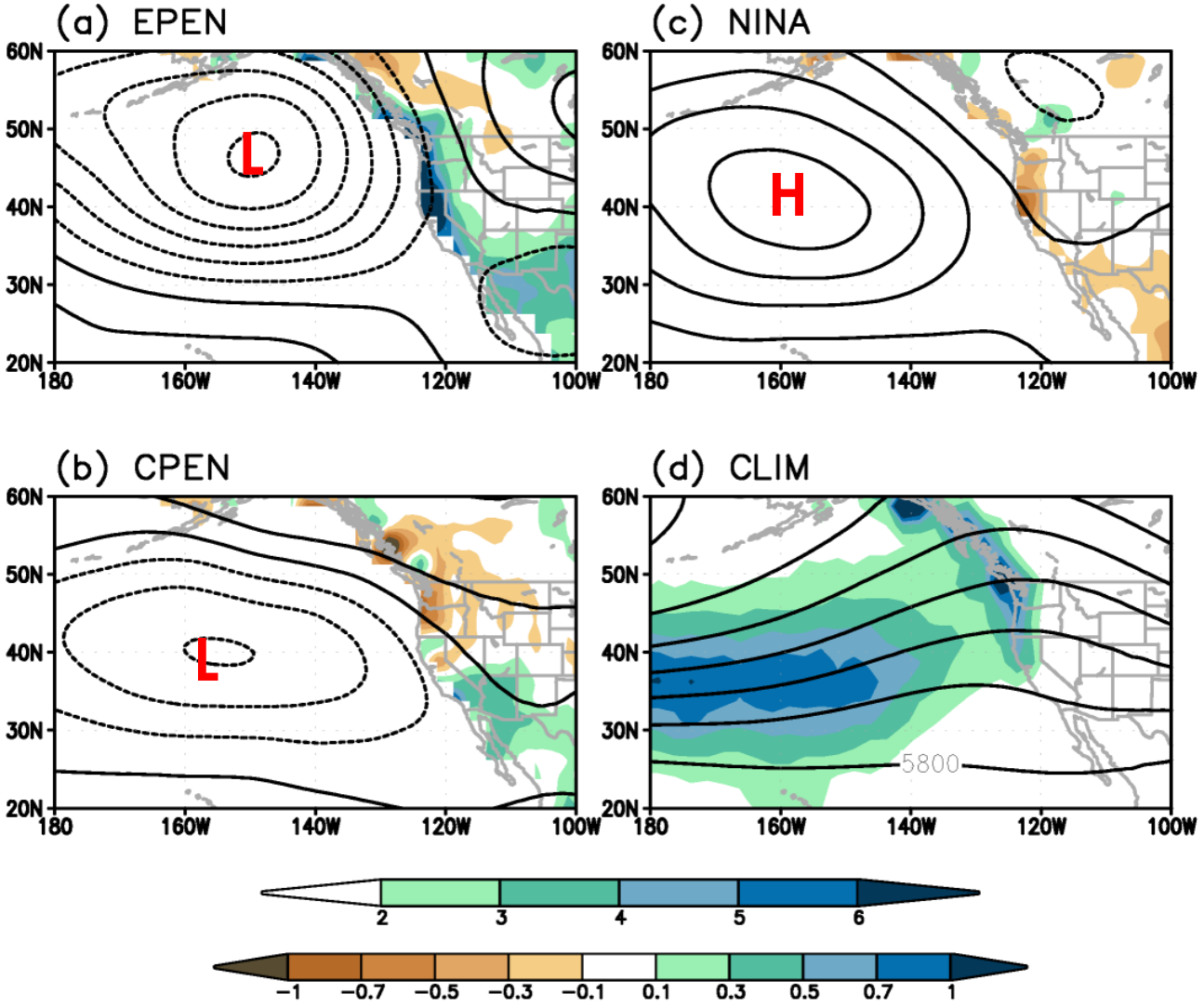
$$\frac{\partial \langle q \rangle}{\partial t} + \nabla \cdot Q = E - P$$

Shading: Moisture flux divergence

Vector: Moisture flux

Winter precipitation

Precipitation (CMAP) and 500GPH anomalies



Relative contribution of multi-factors on mean moisture flux

$$\frac{\partial \langle q \rangle}{\partial t} + \nabla \cdot Q = E - P$$

1) Low-frequency vs. synoptic

$$\bar{Q} = \bar{Q}^m + \bar{Q}^{LF} + \bar{Q}^s + \bar{Q}^R$$

LF: low-frequency (>10 days)
S: synoptic (<10 days)

2) Dynamic vs Thermodyn. factor

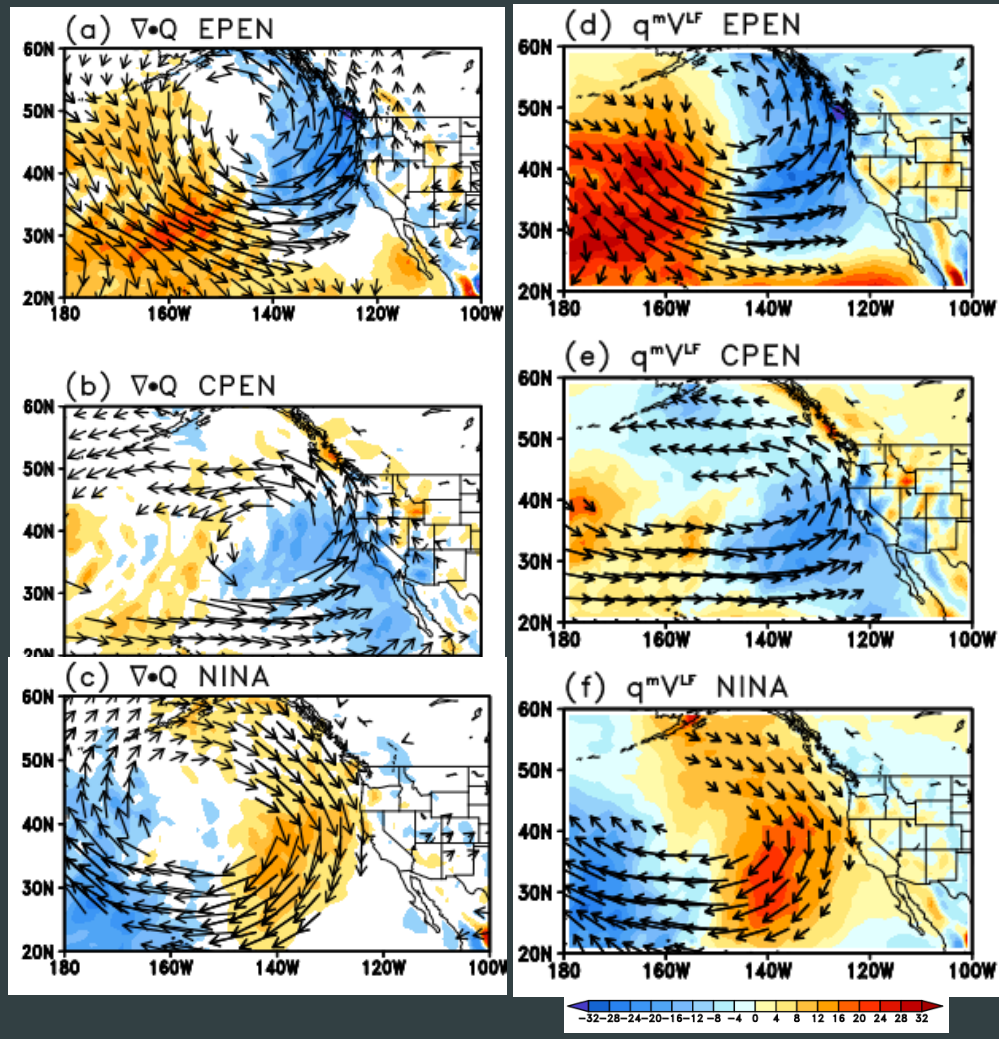
$$\bar{Q}^{LF} \sim < \bar{q}V^{LF} + q^{LF}\,\bar{V} + q^{LF}\,V^{LF} >$$

3) Advection vs. divergence

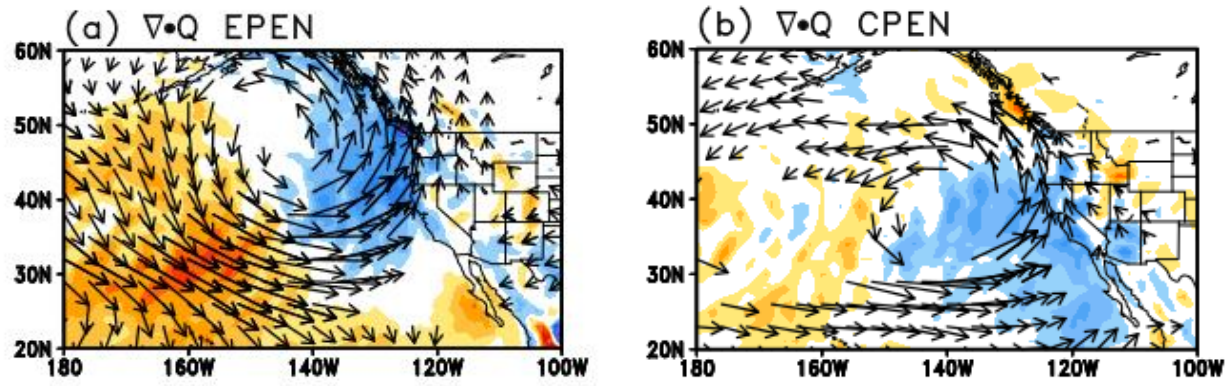
$$\nabla \cdot Q^{LF} \sim (q\nabla \cdot V)^{LF} + (V \cdot \nabla q)^{LF}$$

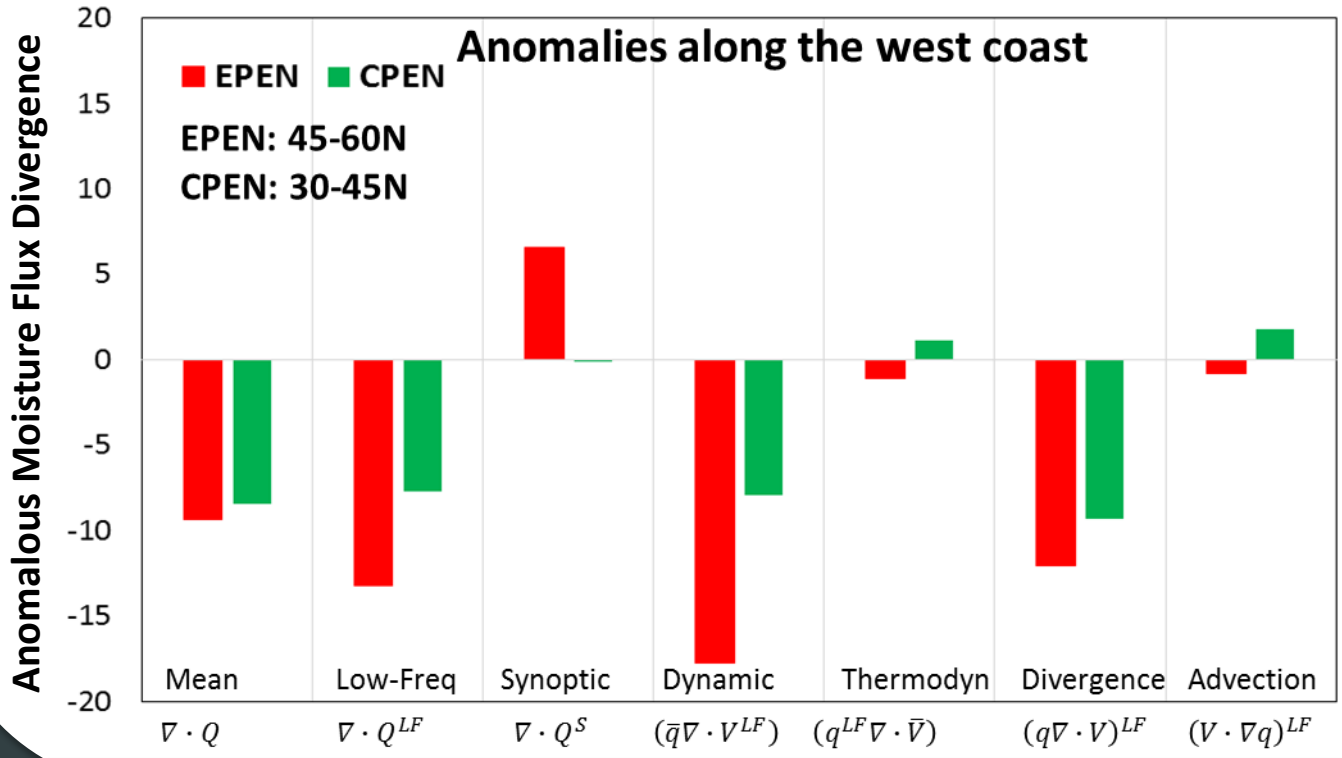
Seasonal mean MF

$\bar{q}V^{LF}$
changes in circulation



Moisture flux divergence

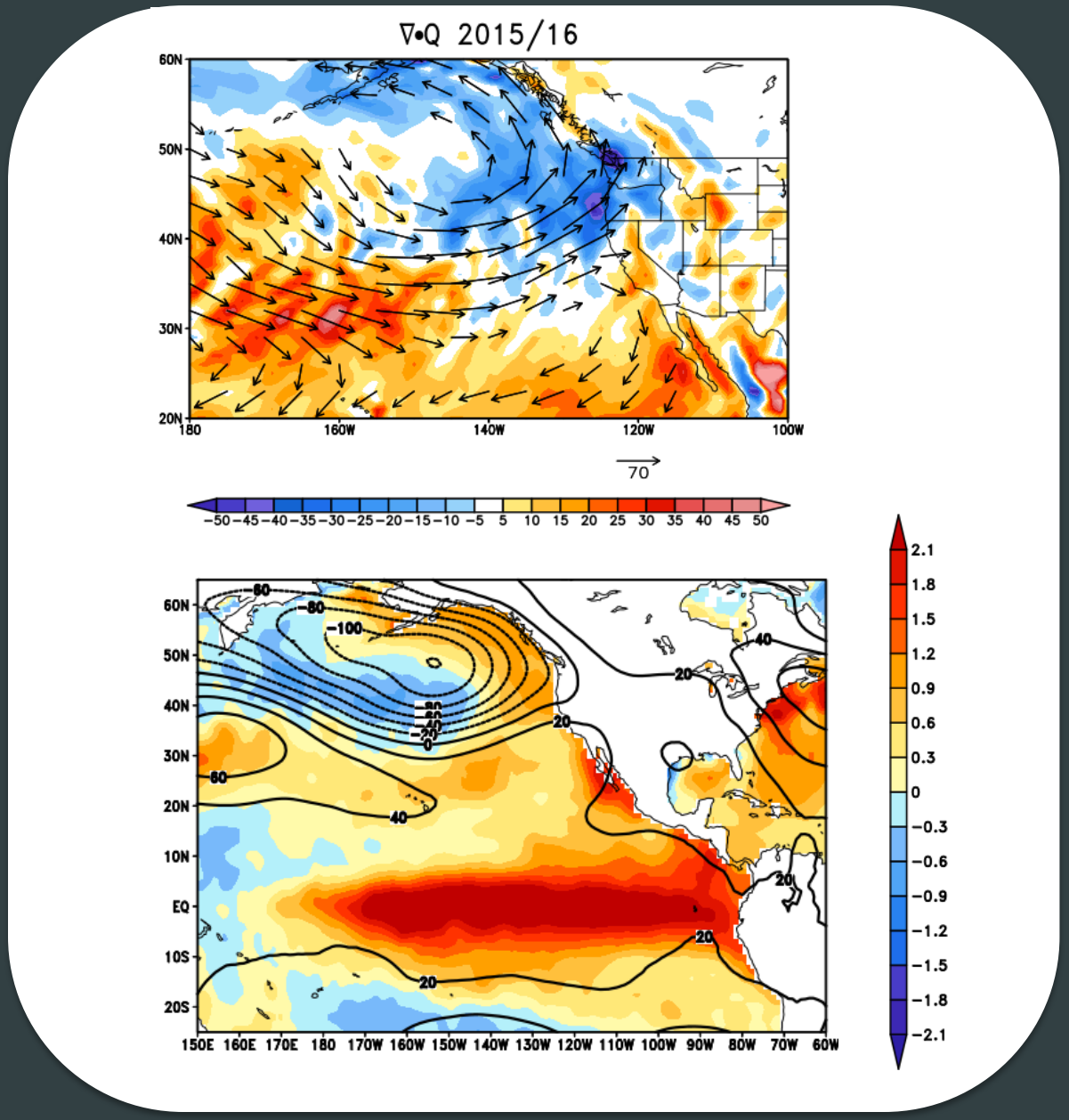




Last winter: 2015/2016 DJF

Moisture flux divergence & moisture flux

SST & 500GPH anomaly



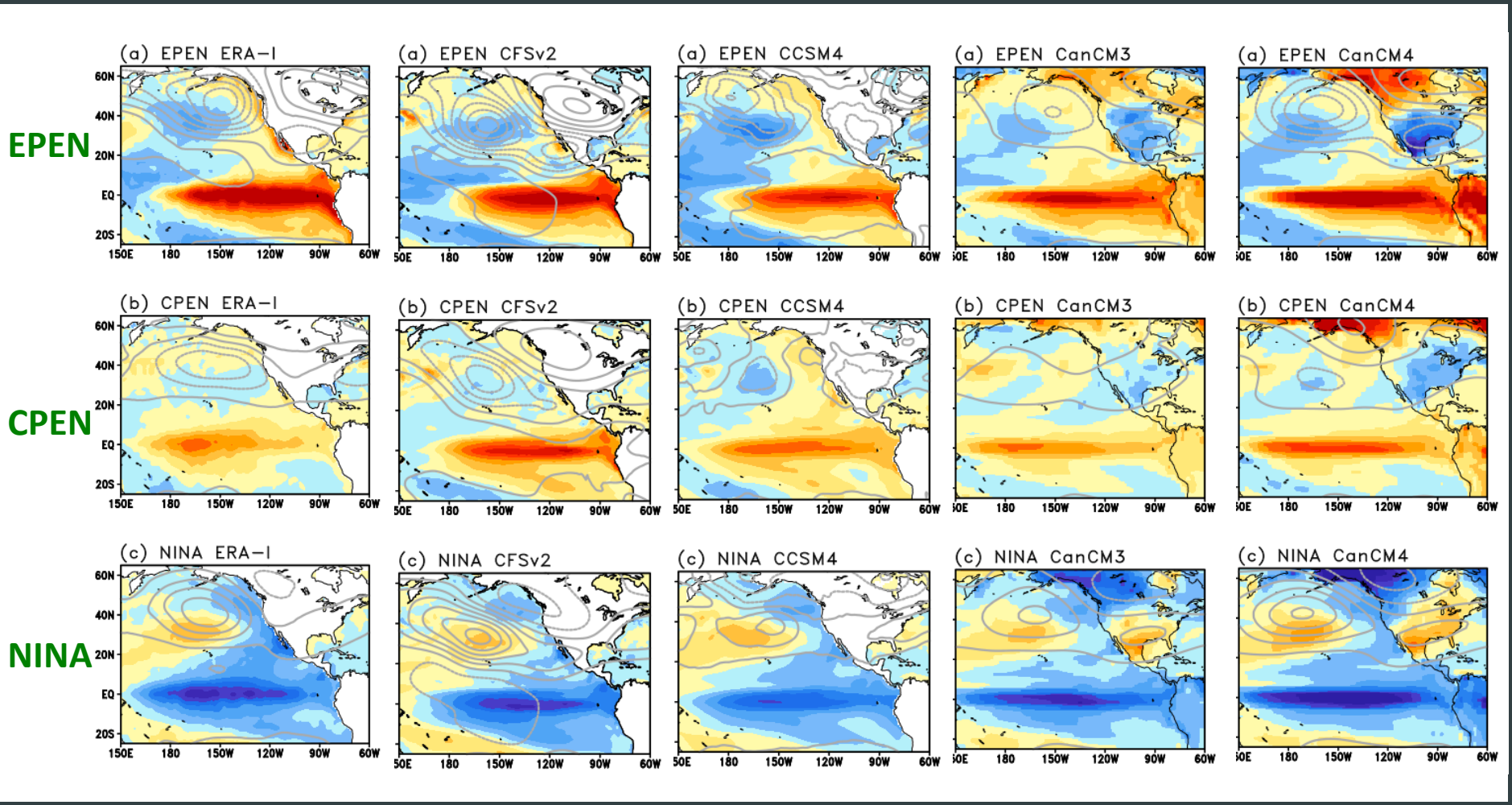
NMME hindcasts

- **ENSO prediction**
- **Moisture flux prediction**

  - Daily data: u, v, Ts, q, ps (1000~300hPa)
  - DJF mean
  - CFSv2 : 1982-2010 12 members (IC: 10/28~11/07)
  - CanCM3: 1981-2009 10 members (IC: Nov-01)
  - CanCM4: 1981-2009 10 members (IC: Nov-01)
  - CCSM4 : 1982-2012 10 members (IC: Nov01)

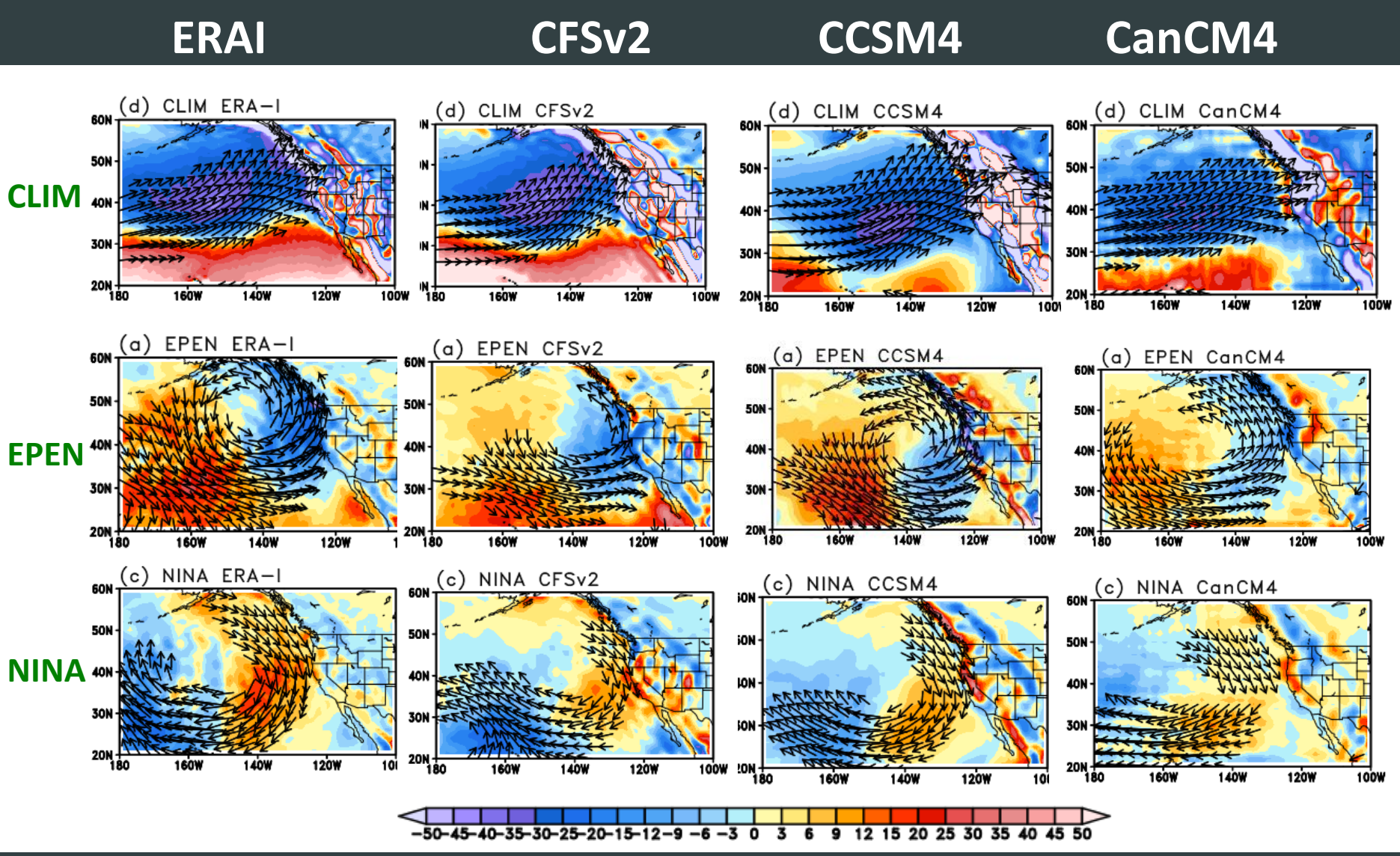
$$Q = \frac{1}{g}\int_{Ps}^{300} \vec{V} \cdot q \, dP$$

ENSO prediction

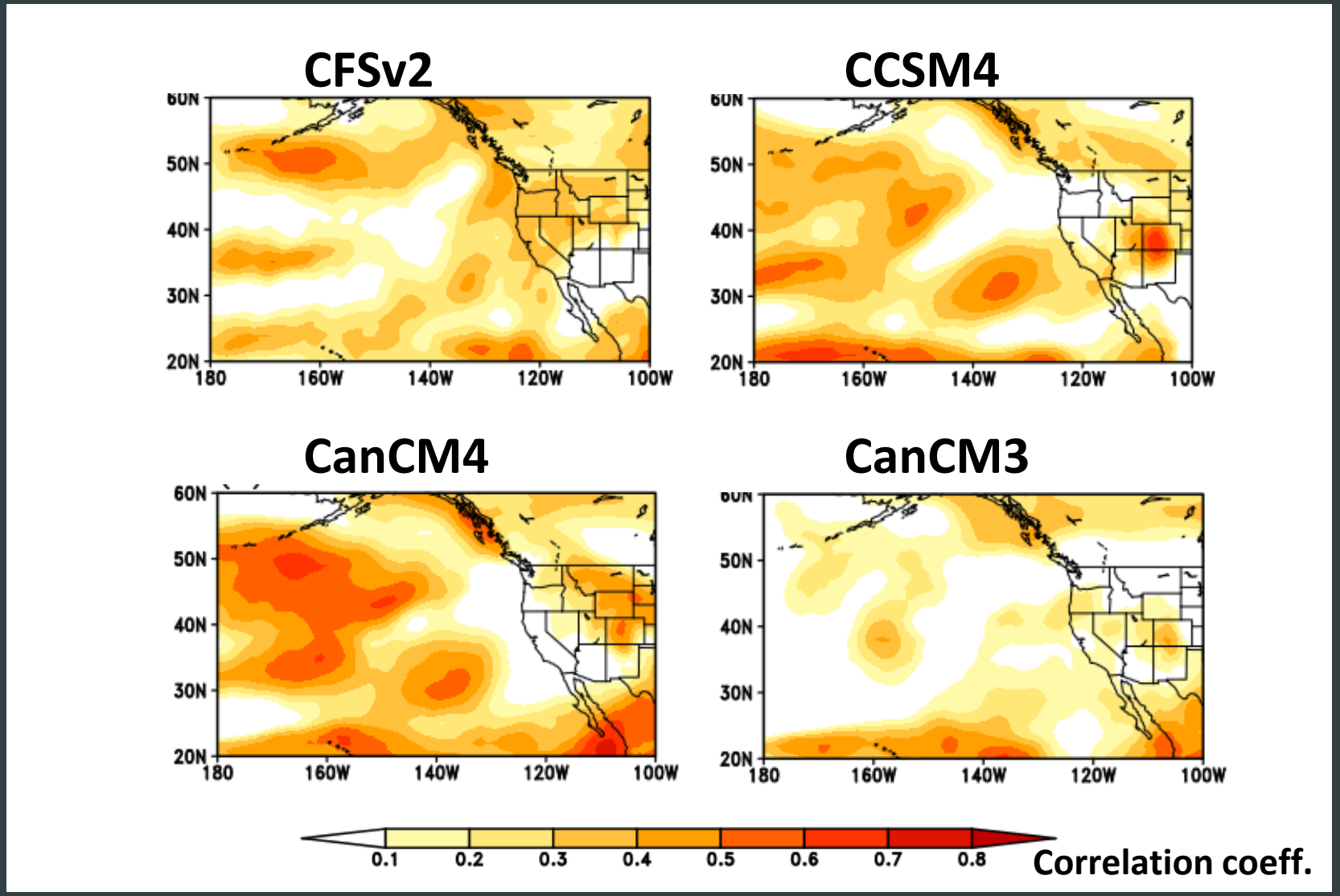


* Contour interval: 20 m
* CanCM3 and CanCM4: Surface temperature

DJF Moisture Flux (IC: Nov)



Prediction skill: DJF Moisture Flux



Summary

- The year-to-year changes in cool season atmospheric rivers (ARs) and moisture transport over the northeast Pacific and western North America are associated with ENSO variability.

- In CP El Nino winters, the Aleutian low shifts further southward relative to its position in EPEN, resulting an increase in the frequency and intensity of landfalling ARs over the southwestern US.

- Utilizing the moisture budget equation, the change in low-frequency mass convergence by circulation is the main reason for the anomalous moisture transport in different ENSO phases.

- While the prediction skill is still low over the Northeast Pacific, the NMME hindcasts simulate the ENSO-moisture flux relationship, thus have potential to predict the seasonal moisture flux and AR activity.

Thank you

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